UCRL-JC-124510 Abs

Evaluation of First Wall Materials for the National Ignition Facility Target Chamber

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The NIF target-chamber first-wall material must survive high x-ray, stray light, debris, and shrapnel exposures without generating vapors or particulates that will excessively contaminate the final optics debris shields or other components in the target chamber, thereby making them susceptible to subsequent damage. It also must not outgas excessively during chamber pumpdown or activate significantly under high neutron fluxes. Furthermore, it must be cleanable by CO_2 pellets or some other technique to remove target debris and tritium. Finally, the first wall must be developed and fabricated for a reasonable cost. These requirements provide a challenge to material science.

The first wall would consist of removable panels fastened to the inside of the chamber. Existing data and preliminary modeling were used to select materials for evaluation. Two criteria were a large x-ray deposition depth, which indicates a low-Z material, and a high melting or boiling point to minimize ablation. These criteria limited the list of potential candidates to various forms of B, B_4C, C, Al_2O_3, $MgAl_2O_4$, SiC, Si_3N_4, and SiO_2. Be was not considered seriously due to environmental, health, and safety issues. Potential first-wall materials were acquired from a variety of suppliers in both plasma-sprayed coatings, which offer considerable cost savings, and solid panels.

As expected, B, B_4C and C compounds performed the best under x-ray exposure, the primary threat to the first wall. Roughening due to crazing and other mechanisms complicated material removal measurements, but estimates were possible to the accuracy required to distinguish between various material groups. Thermomechanical modeling was used to understand the relative contributions of vaporization and liquid and solid spall. Damage thresholds for laser light exposure were lower for the dark materials, but B_4C performed adequately. Material collected on facing optics was mostly particulate, and only C and SiC had significant vapor-deposited films. While brown thin films drastically lower the damage threshold, particulate B_4C is largely blown off the optic by a laser pulse, thereby delaying major optical damage for 10 or more shots at useful fluences. Al_2O_3 and B_4C thermal spray coatings outgassed much more than solid panels of B_4C, but B_4C coatings with ca. 5% porosity would be acceptable. The low-porosity B_4C coatings and hot-pressed panels withstood aggressive CO_2 cleaning with minimal erosion equally well.

Coupons of various B_4C materials (hot pressed and plasma sprayed) were cyclically exposed to CO_2 cleaning and weeks of exposure to target emissions to assess the long-term durability of potential first-wall forms. Placement of the samples resulted in a maximum x-ray fluence of 1 J/cm^2, comparable to a 10 MJ yield shot on the NIF. Target shrapnel caused most of the observed damage. Craters were commonly a few hundred μm deep but did not penetrate B_4C coatings of 0.5 mm. Aged metal deposits proved harder to remove with CO_2 cleaning from the panels than thin films deposited by ordinary evaporative coating. Still unresolved is how clean the panels have to be to reduce revaporization of metal deposits from the first wall to the debris shield to an acceptable level.

*This work was performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract No. W-7405-Eng-48.